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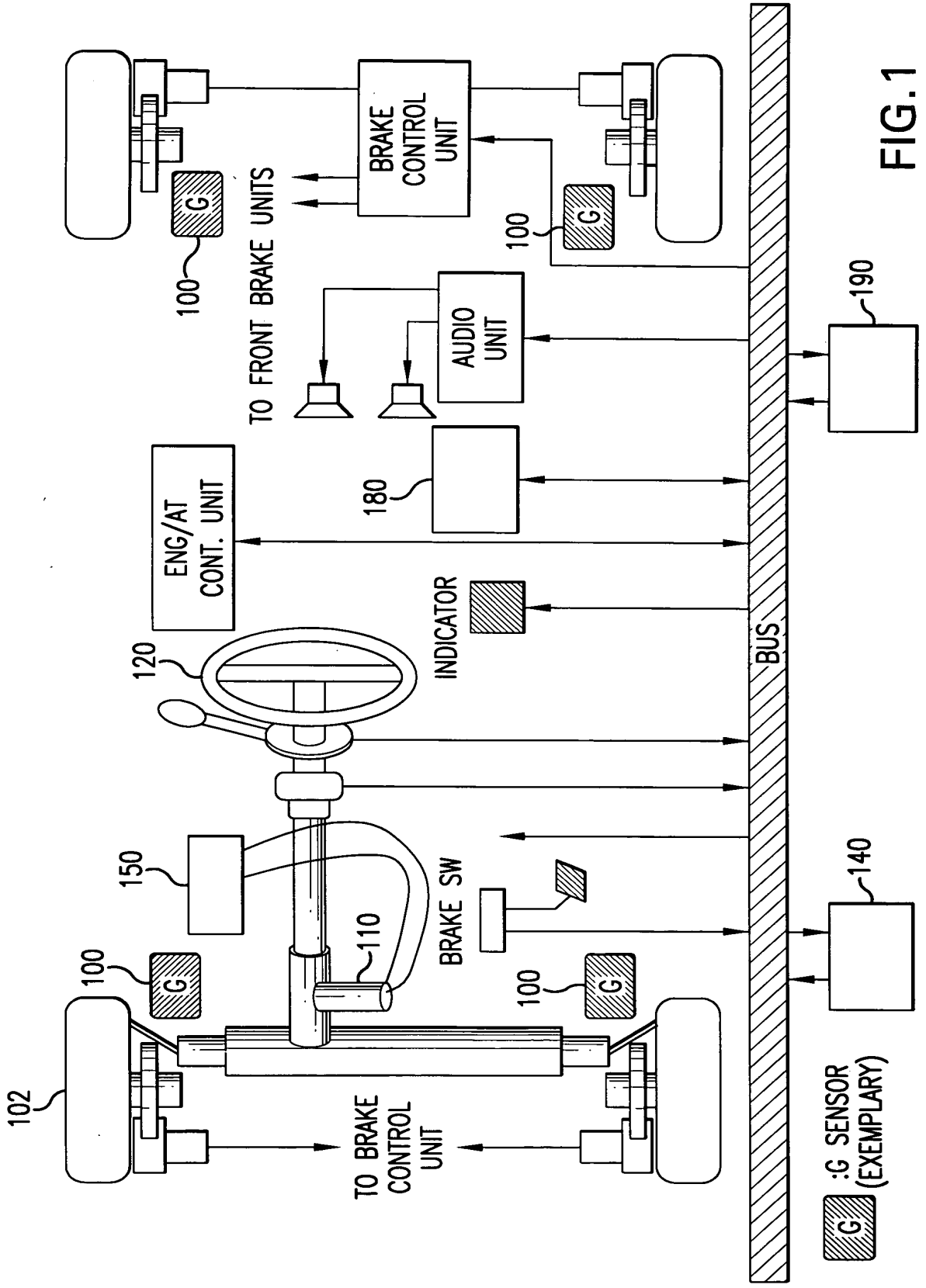

FIG. 1

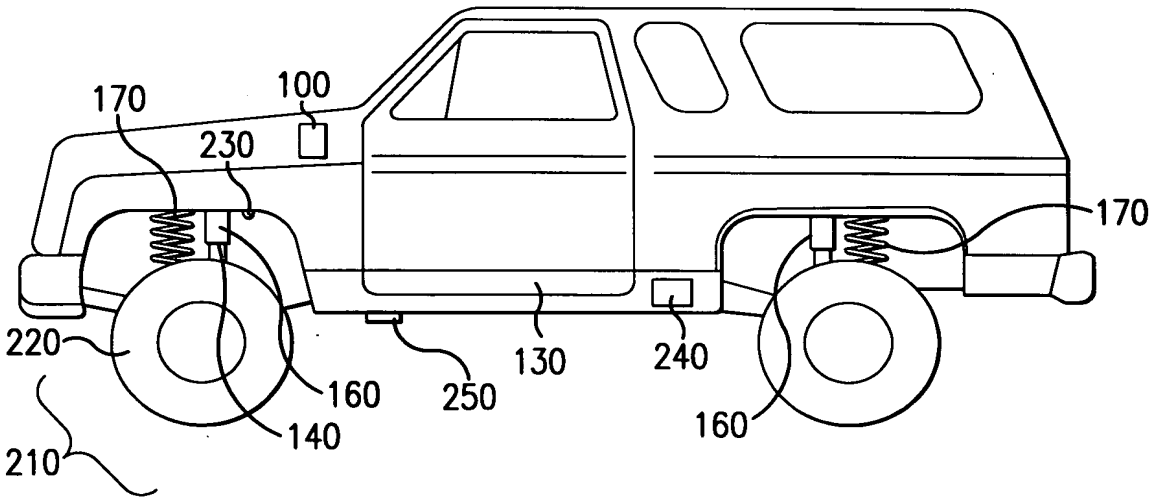

FIG.2

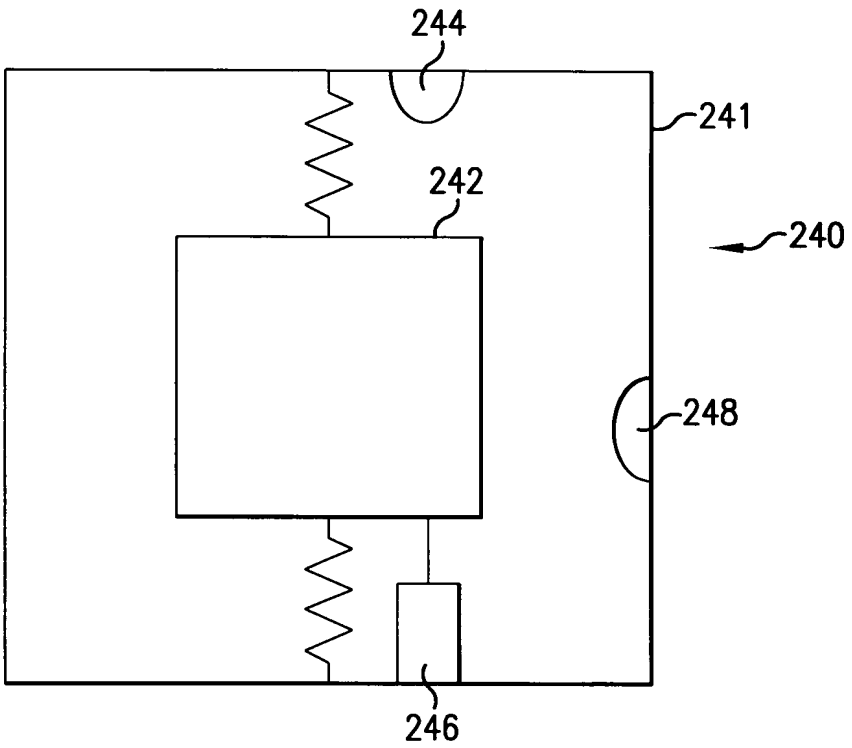

FIG.3

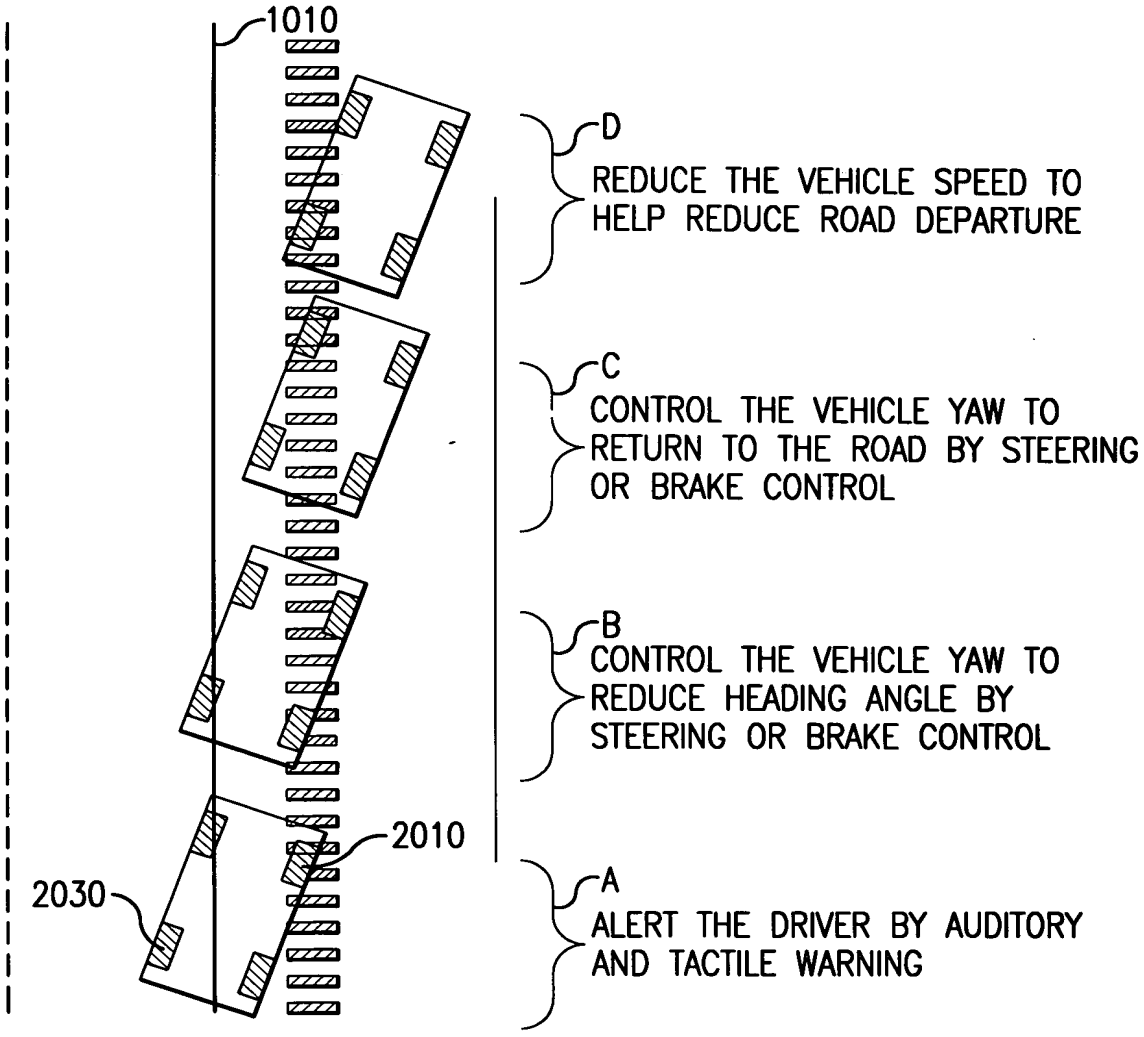
1010
D
REDUCE THE VEHICLE SPEED TO HELP REDUCE ROAD DEPARTURE
C
CONTROL THE VEHICLE YAW TO RETURN TO THE ROAD BY STEERING OR BRAKE CONTROL
B
CONTROL THE VEHICLE YAW TO REDUCE HEADING ANGLE BY STEERING OR BRAKE CONTROL
2010
2030
A
ALERT THE DRIVER BY AUDITORY AND TACTILE WARNING

FIG.4

CALCULATION OF THE LATERAL SPEED AT DEVIATION

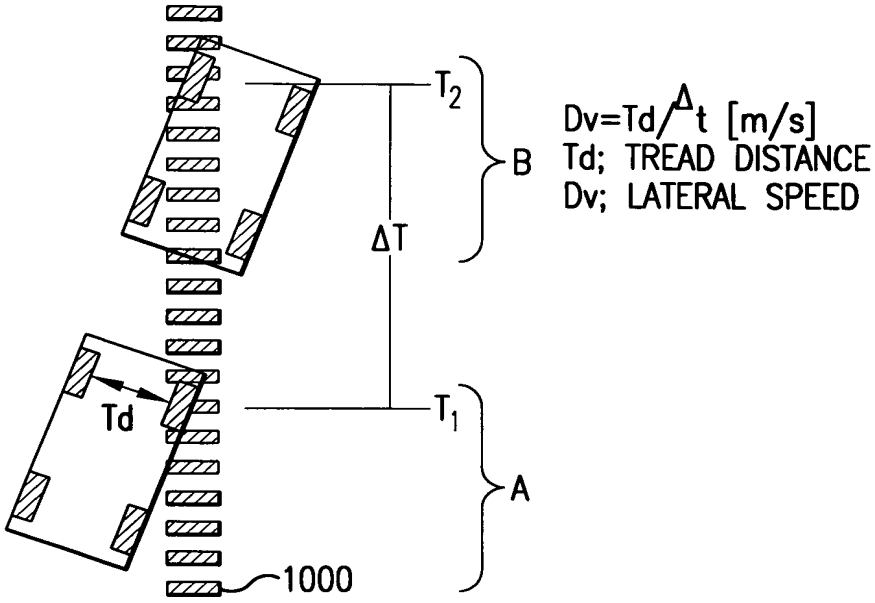

FIG.5a

CALCULATION OF THE HEADING ANGLE AT DEVIATION

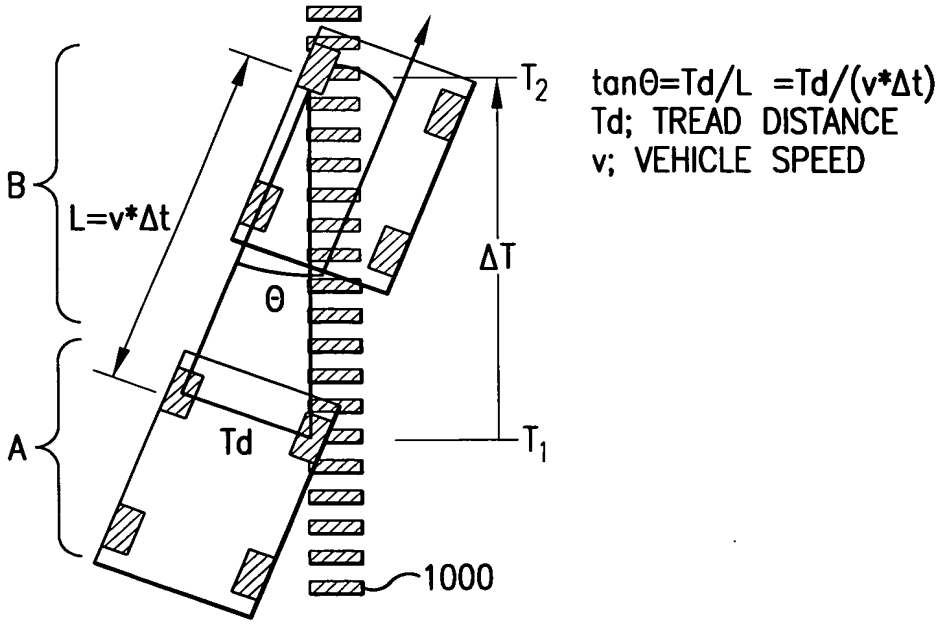

FIG.5b

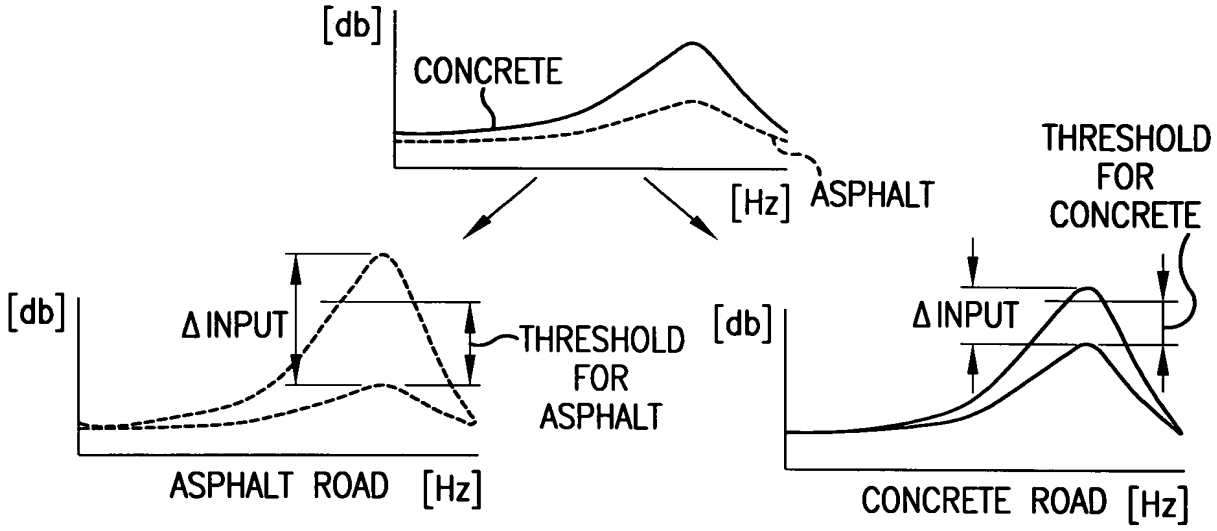
[db]
CONCRETE
[Hz]
ASPHALT
THRESHOLD FOR CONCRETE
[db]
Δ INPUT
THRESHOLD FOR ASPHALT
ASPHALT ROAD [Hz]
[db]
Δ INPUT
CONCRETE ROAD [Hz]

FIG.6

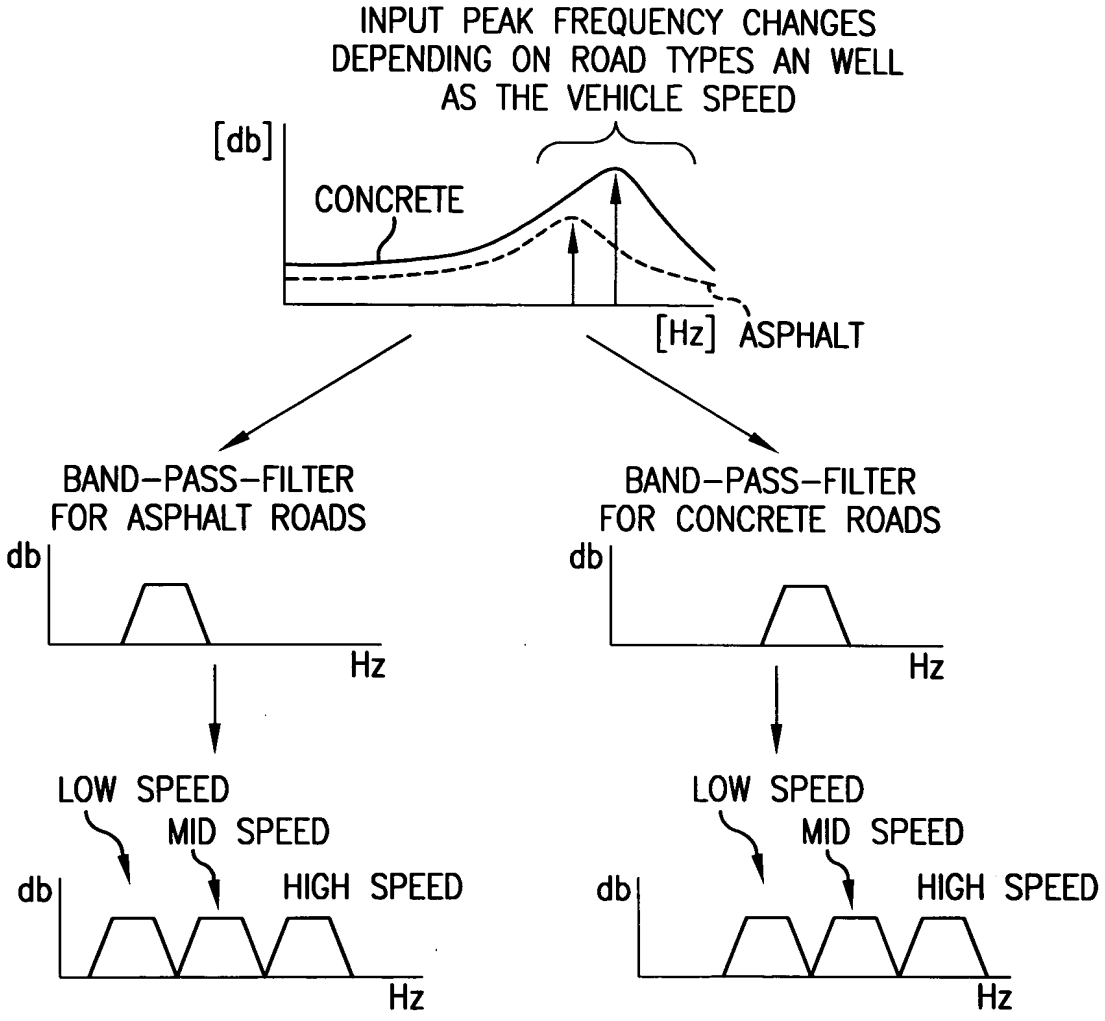
INPUT PEAK FREQUENCY CHANGES DEPENDING ON ROAD TYPES AN WELL AS THE VEHICLE SPEED
[db]
CONCRETE
[Hz] ASPHALT
BAND-PASS-FILTER FOR ASPHALT ROADS
db
Hz
LOW SPEED
MID SPEED
HIGH SPEED
db
Hz
BAND-PASS-FILTER FOR CONCRETE ROADS
db
Hz
LOW SPEED
MID SPEED
HIGH SPEED
db
Hz

FIG.7

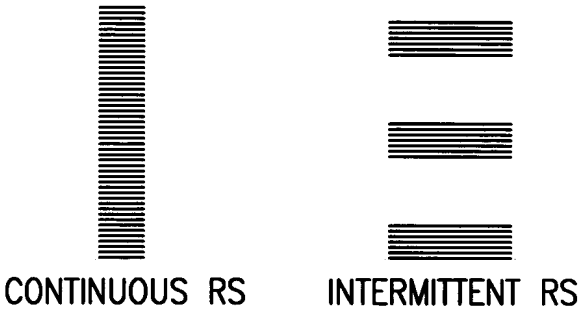

FIG.8

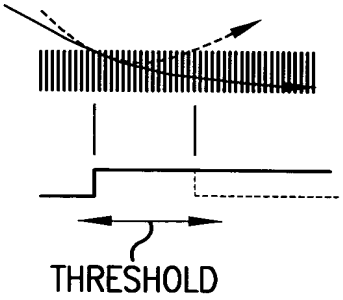

FIG.9

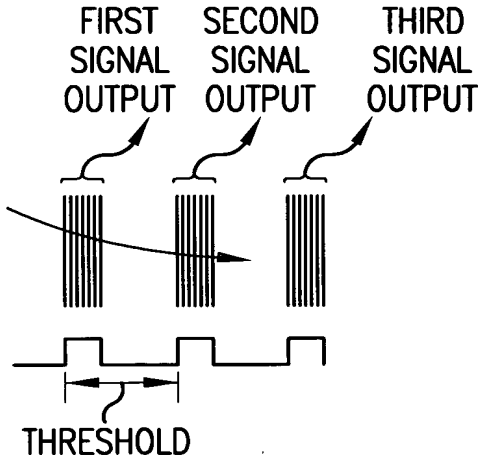

FIG.10

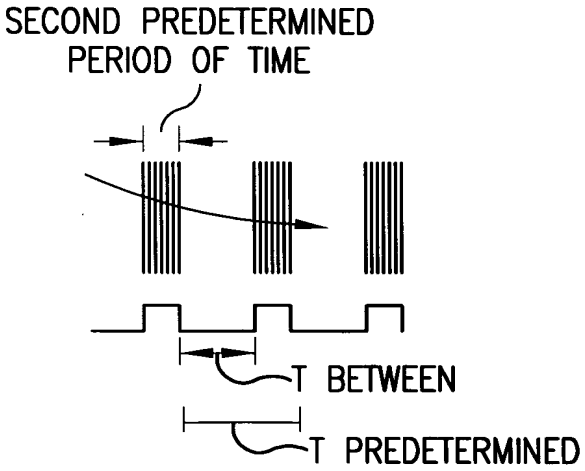

FIG.11

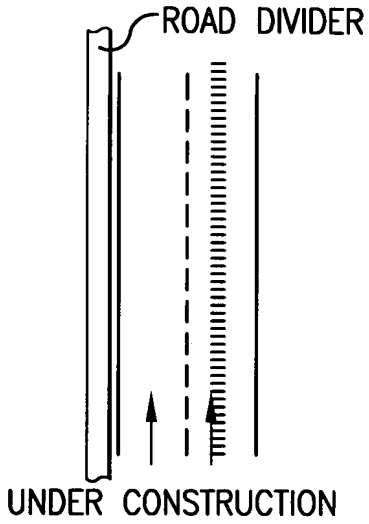

FIG.12

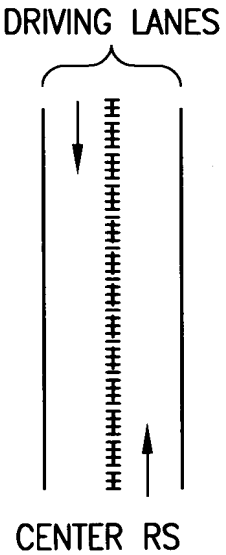

FIG.13

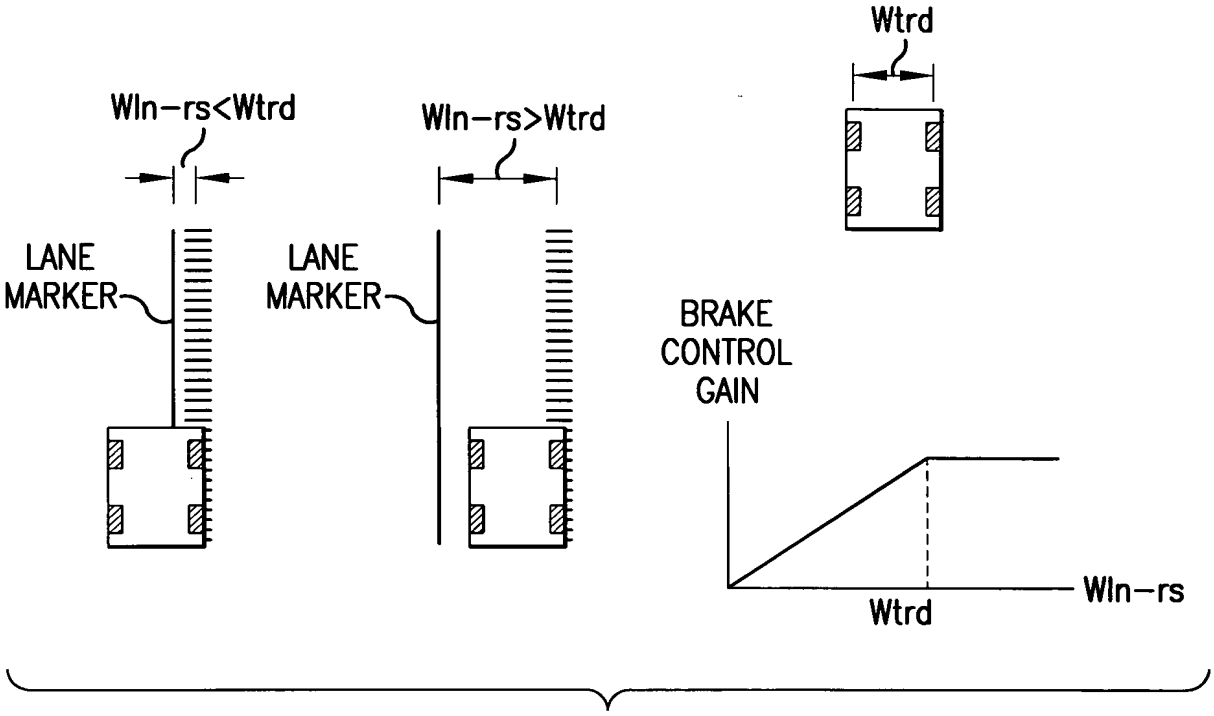
Wtrd
Win−rs<Wtrd
Win−rs>Wtrd
LANE MARKER
LANE MARKER
BRAKE CONTROL GAIN
Wtrd
Win−rs

FIG.14

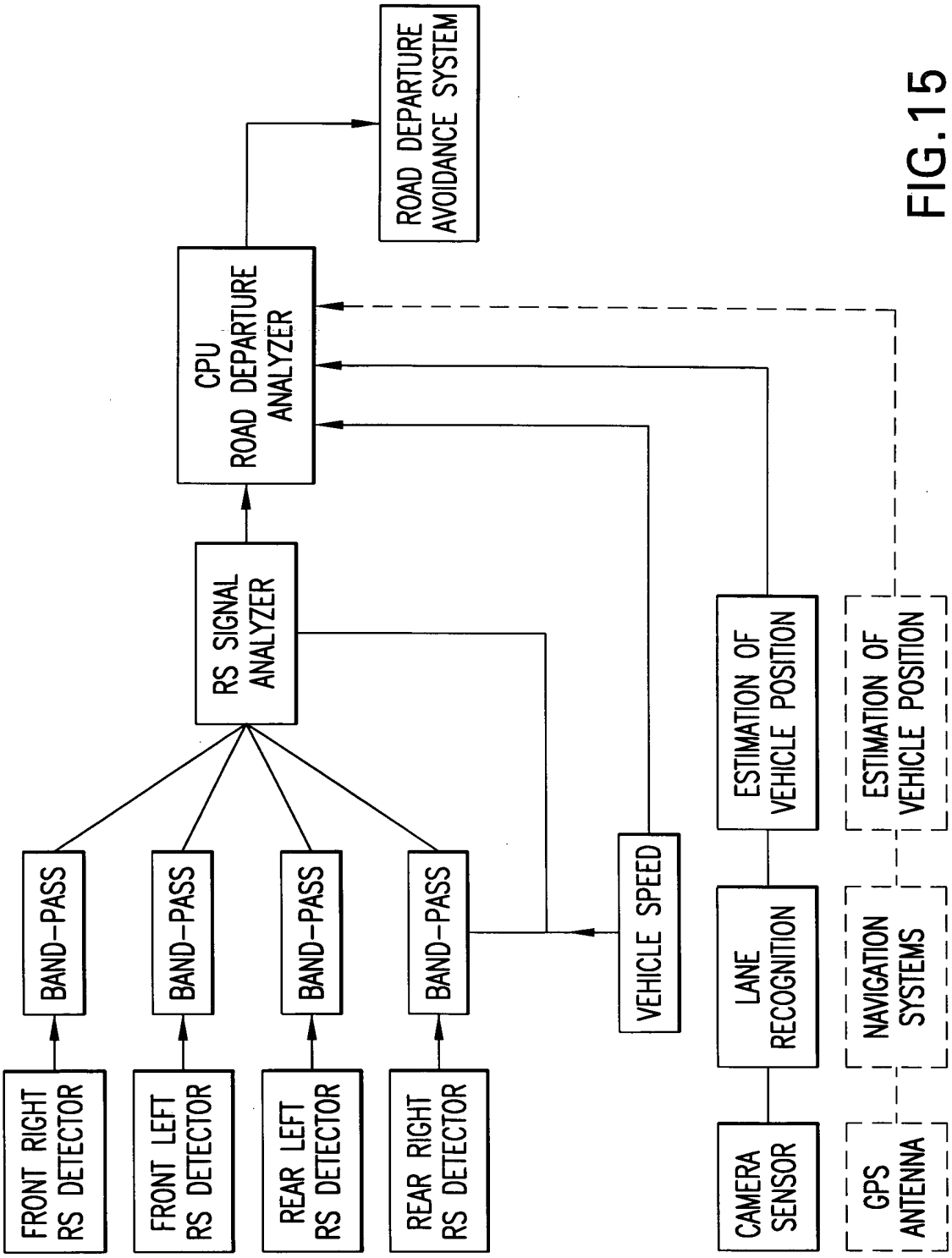
ROAD DEPARTURE AVOIDANCE SYSTEM
CPU ROAD DEPARTURE ANALYZER
RS SIGNAL ANALYZER
BAND-PASS
BAND-PASS
BAND-PASS
BAND-PASS
FRONT RIGHT RS DETECTOR
FRONT LEFT RS DETECTOR
REAR LEFT RS DETECTOR
REAR RIGHT RS DETECTOR
VEHICLE SPEED
ESTIMATION OF VEHICLE POSITION
ESTIMATION OF VEHICLE POSITION
LANE RECOGNITION
NAVIGATION SYSTEMS
CAMERA SENSOR
GPS ANTENNA

FIG.15

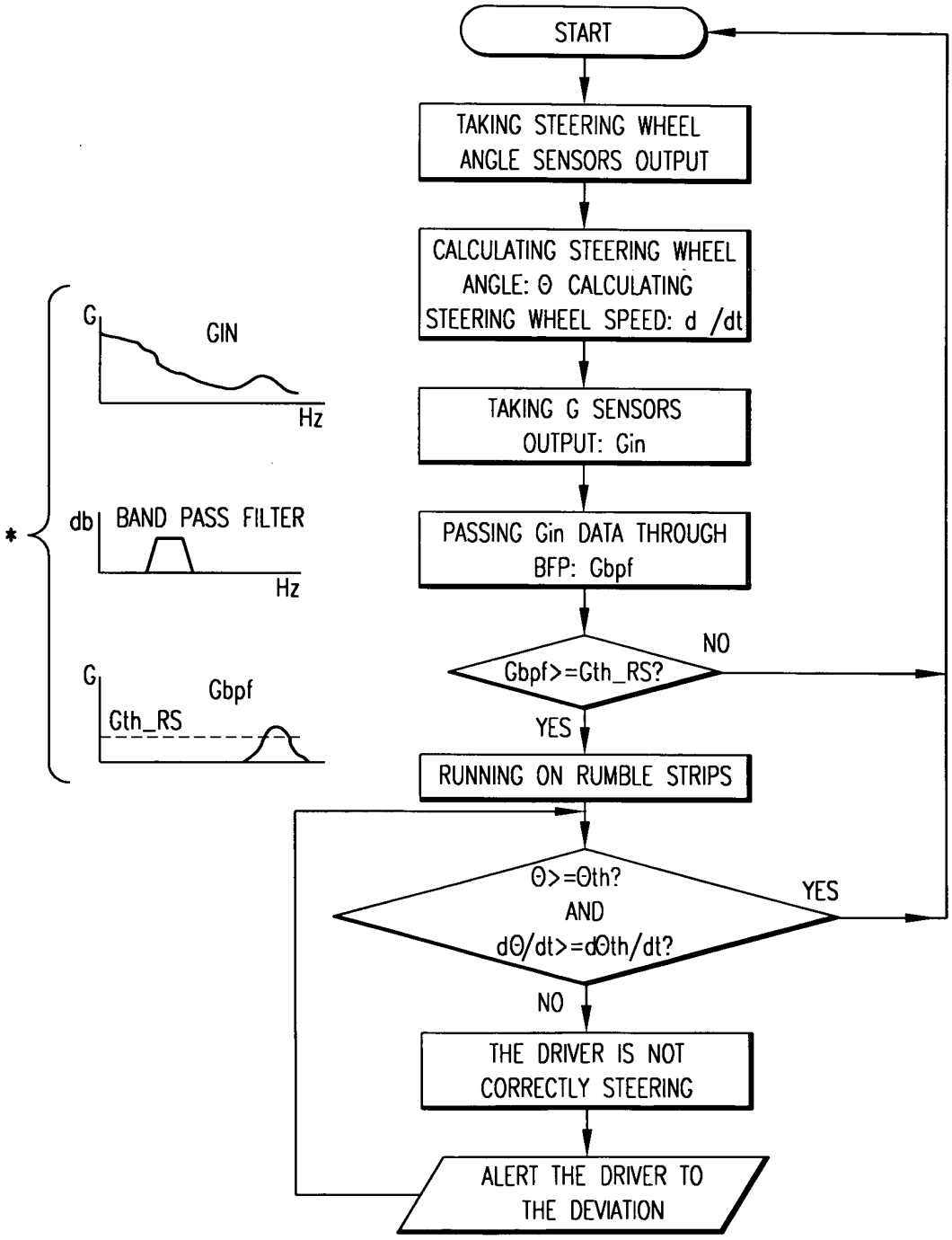
START
TAKING STEERING WHEEL ANGLE SENSORS OUTPUT
CALCULATING STEERING WHEEL ANGLE: Θ CALCULATING STEERING WHEEL SPEED: d /dt
TAKING G SENSORS OUTPUT: Gin
PASSING Gin DATA THROUGH BFP: Gbpf
Gbpf>=Gth_RS?
NO
YES
RUNNING ON RUMBLE STRIPS
Θ>=Θth? AND dΘ/dt>=dΘth/dt?
YES
NO
THE DRIVER IS NOT CORRECTLY STEERING
ALERT THE DRIVER TO THE DEVIATION
G
GIN
Hz
db
BAND PASS FILTER
Hz
G
Gbpf
Gth_RS
*

FIG.16

EXEMPLARY CUT-OFF FREQUENCIES OF BAND-PASS FILTER IN RESPONSE TO VEHICLE SPEED. THE PATTERN OF RUMBLE STRIPS: CYCLE DISTANCE: 30.48cm (1 FOOT)
140+km/h 128Hz BPF#1
120~140km/h 109 Hz BPF#2
100~120 km/h 91 Hz BPF#3
80~100km/h 72 Hz BPF#4
60~80km/h 55Hz BPF#5

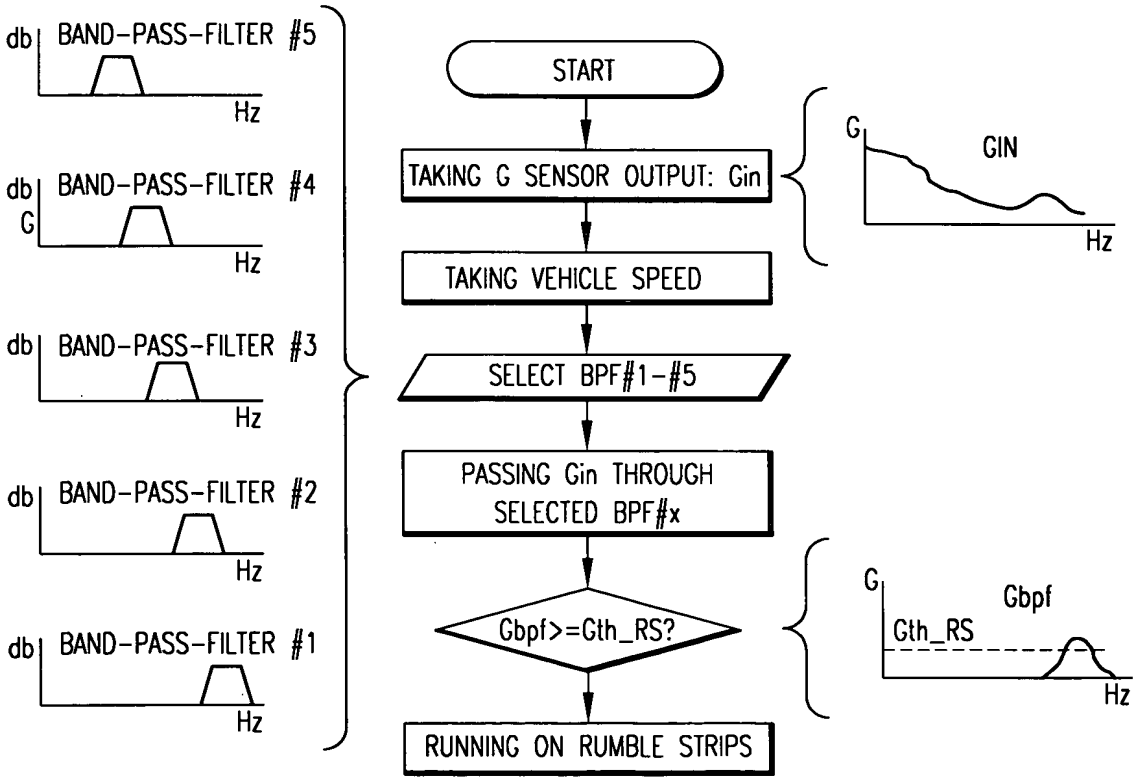

FIG.17

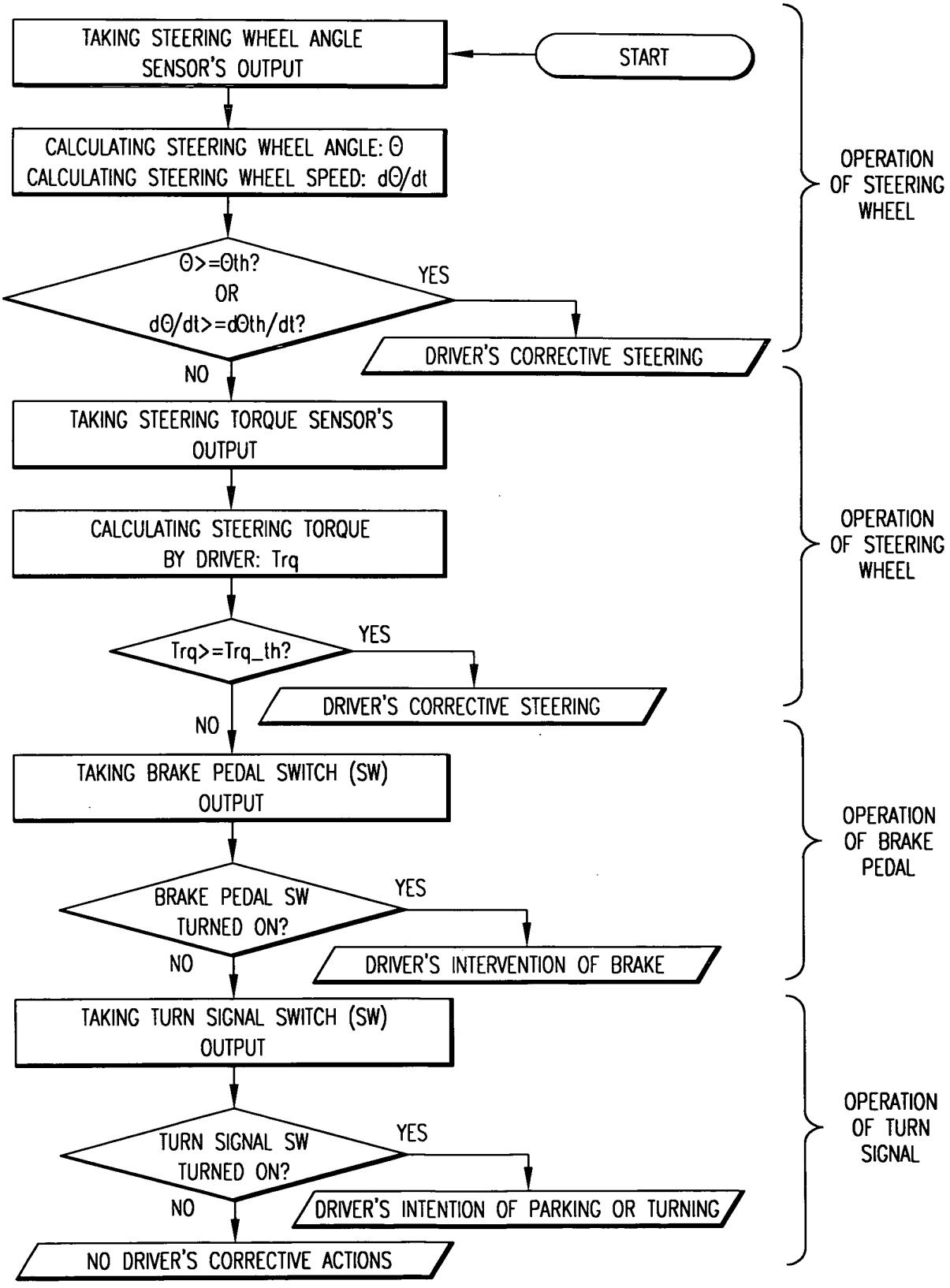
START
TAKING STEERING WHEEL ANGLE SENSOR'S OUTPUT
CALCULATING STEERING WHEEL ANGLE: Θ
CALCULATING STEERING WHEEL SPEED: dΘ/dt
Θ>=Θth? OR dΘ/dt>=dΘth/dt?
YES
DRIVER'S CORRECTIVE STEERING
NO
TAKING STEERING TORQUE SENSOR'S OUTPUT
CALCULATING STEERING TORQUE BY DRIVER: Trq
Trq>=Trq_th?
YES
DRIVER'S CORRECTIVE STEERING
NO
TAKING BRAKE PEDAL SWITCH (SW) OUTPUT
BRAKE PEDAL SW TURNED ON?
YES
DRIVER'S INTERVENTION OF BRAKE
NO
TAKING TURN SIGNAL SWITCH (SW) OUTPUT
TURN SIGNAL SW TURNED ON?
YES
DRIVER'S INTENTION OF PARKING OR TURNING
NO
NO DRIVER'S CORRECTIVE ACTIONS
OPERATION OF STEERING WHEEL
OPERATION OF STEERING WHEEL
OPERATION OF BRAKE PEDAL
OPERATION OF TURN SIGNAL

FIG.18

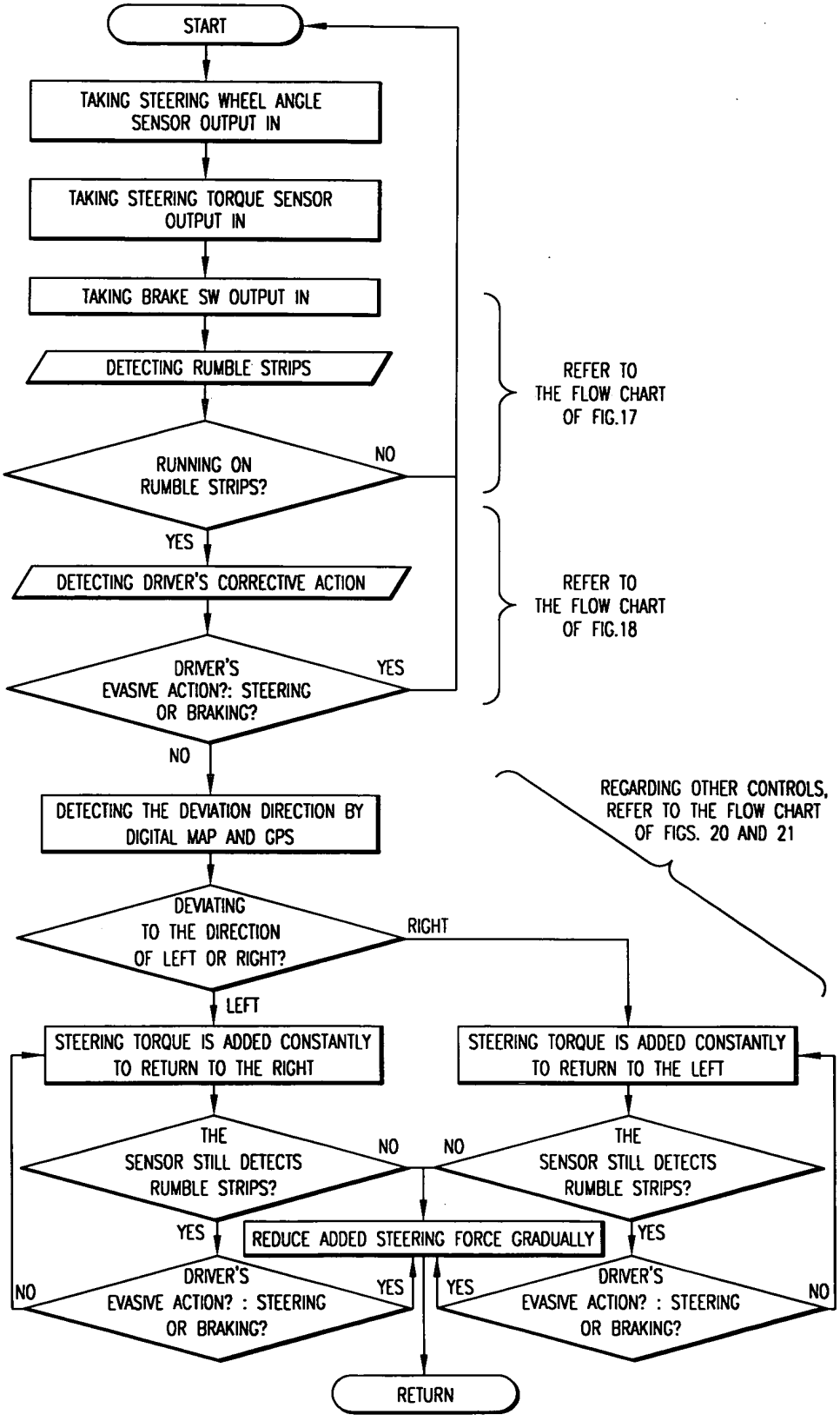
START
TAKING STEERING WHEEL ANGLE SENSOR OUTPUT IN
TAKING STEERING TORQUE SENSOR OUTPUT IN
TAKING BRAKE SW OUTPUT IN
DETECTING RUMBLE STRIPS
RUNNING ON RUMBLE STRIPS?
NO
YES
REFER TO THE FLOW CHART OF FIG.17
DETECTING DRIVER'S CORRECTIVE ACTION
DRIVER'S EVASIVE ACTION?: STEERING OR BRAKING?
YES
NO
REFER TO THE FLOW CHART OF FIG.18
DETECTING THE DEVIATION DIRECTION BY DIGITAL MAP AND GPS
REGARDING OTHER CONTROLS, REFER TO THE FLOW CHART OF FIGS. 20 AND 21
DEVIATING TO THE DIRECTION OF LEFT OR RIGHT?
RIGHT
LEFT
STEERING TORQUE IS ADDED CONSTANTLY TO RETURN TO THE RIGHT
STEERING TORQUE IS ADDED CONSTANTLY TO RETURN TO THE LEFT
THE SENSOR STILL DETECTS RUMBLE STRIPS?
NO
NO
THE SENSOR STILL DETECTS RUMBLE STRIPS?
YES
REDUCE ADDED STEERING FORCE GRADUALLY
YES
DRIVER'S EVASIVE ACTION? : STEERING OR BRAKING?
NO
YES
YES
DRIVER'S EVASIVE ACTION? : STEERING OR BRAKING?
NO
RETURN

FIG.19

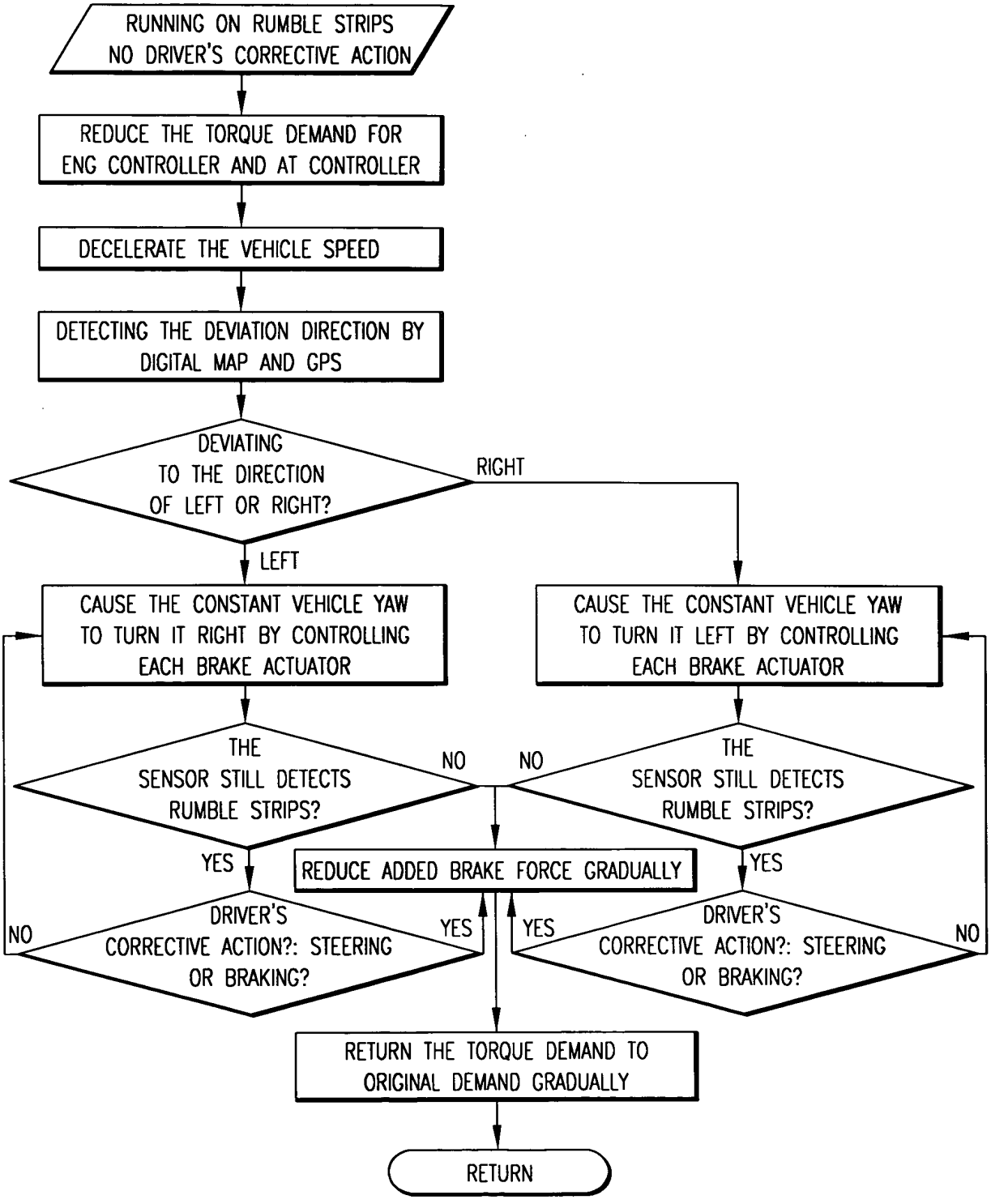
RUNNING ON RUMBLE STRIPS NO DRIVER'S CORRECTIVE ACTION
REDUCE THE TORQUE DEMAND FOR ENG CONTROLLER AND AT CONTROLLER
DECELERATE THE VEHICLE SPEED
DETECTING THE DEVIATION DIRECTION BY DIGITAL MAP AND GPS
DEVIATING TO THE DIRECTION OF LEFT OR RIGHT?
RIGHT
LEFT
CAUSE THE CONSTANT VEHICLE YAW TO TURN IT RIGHT BY CONTROLLING EACH BRAKE ACTUATOR
CAUSE THE CONSTANT VEHICLE YAW TO TURN IT LEFT BY CONTROLLING EACH BRAKE ACTUATOR
THE SENSOR STILL DETECTS RUMBLE STRIPS?
NO
NO
THE SENSOR STILL DETECTS RUMBLE STRIPS?
YES
REDUCE ADDED BRAKE FORCE GRADUALLY
YES
DRIVER'S CORRECTIVE ACTION?: STEERING OR BRAKING?
NO
YES
YES
DRIVER'S CORRECTIVE ACTION?: STEERING OR BRAKING?
NO
RETURN THE TORQUE DEMAND TO ORIGINAL DEMAND GRADUALLY
RETURN

FIG.20

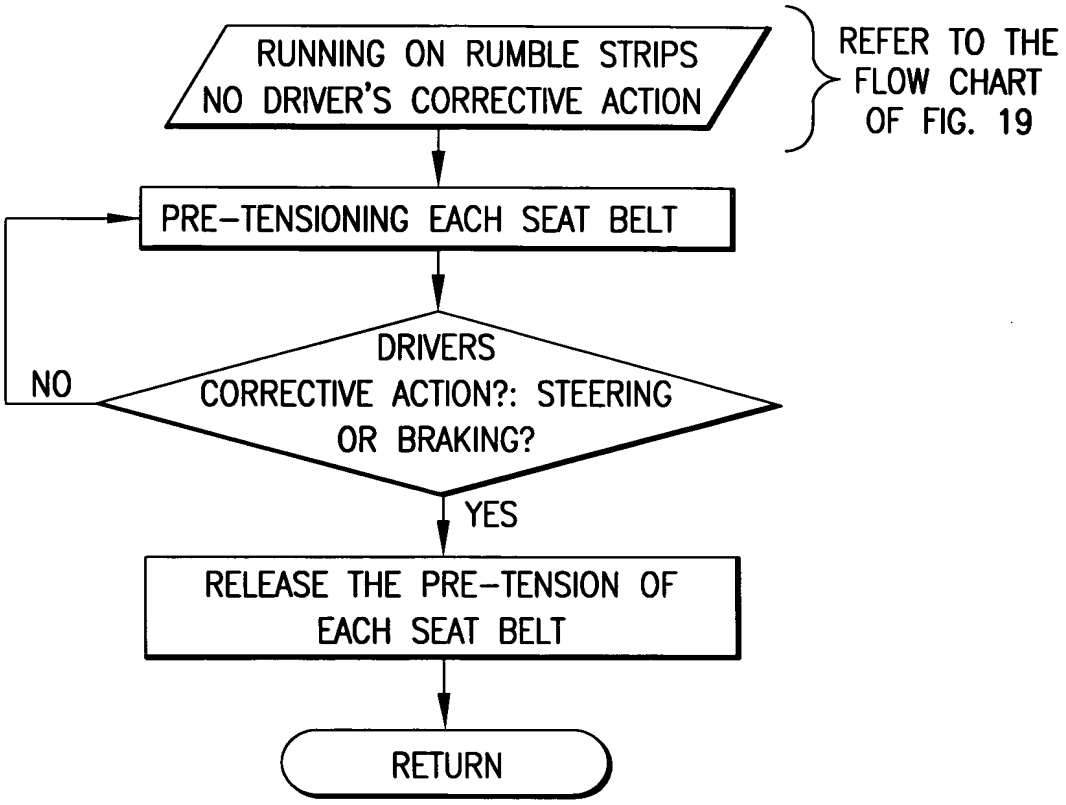
RUNNING ON RUMBLE STRIPS
NO DRIVER'S CORRECTIVE ACTION
REFER TO THE FLOW CHART OF FIG. 19
PRE-TENSIONING EACH SEAT BELT
DRIVERS CORRECTIVE ACTION?: STEERING OR BRAKING?
NO
YES
RELEASE THE PRE-TENSION OF EACH SEAT BELT
RETURN

FIG.21

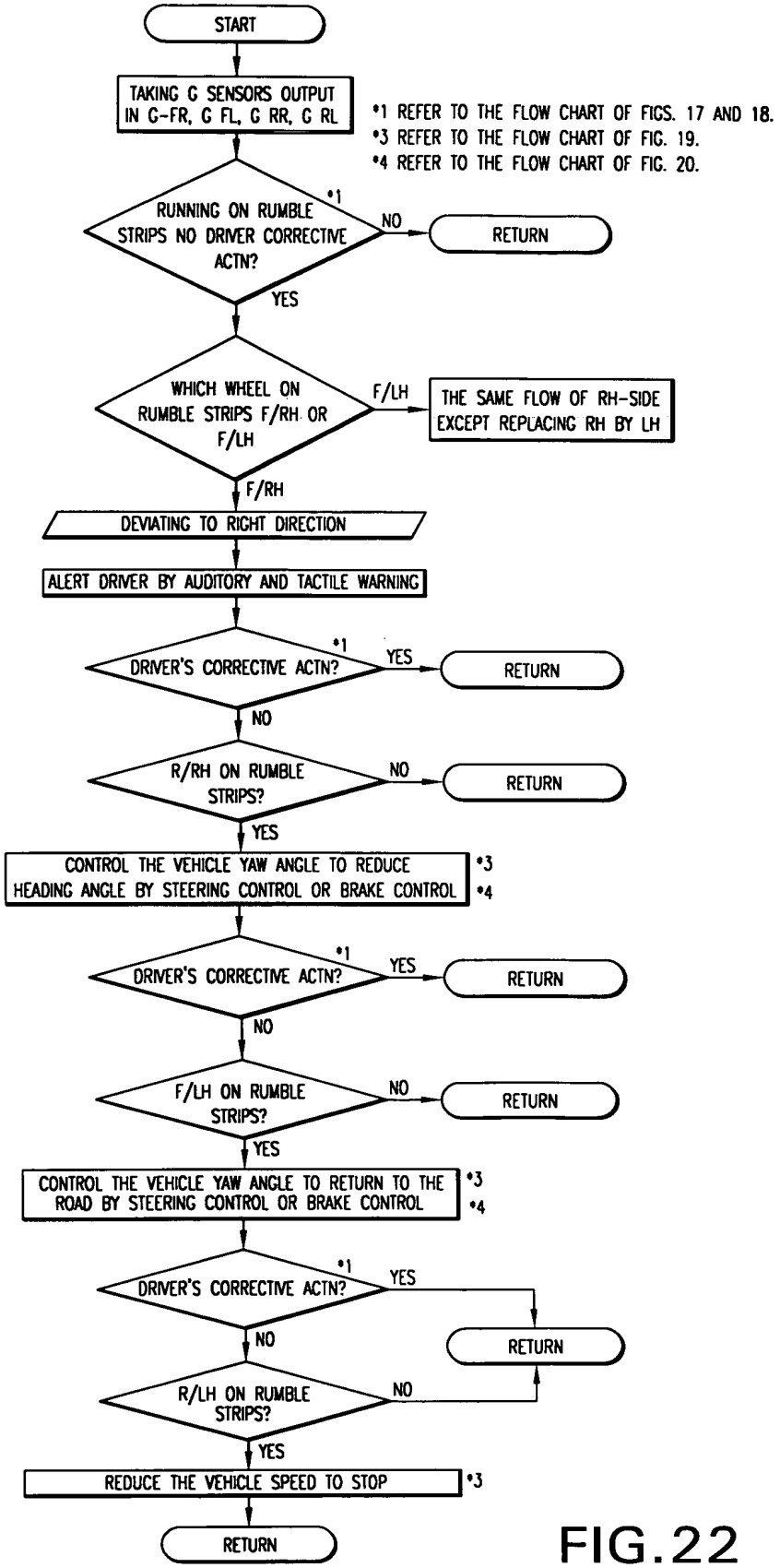
START
TAKING G SENSORS OUTPUT IN G-FR, G FL, G RR, G RL
*1 REFER TO THE FLOW CHART OF FIGS. 17 AND 18.
*3 REFER TO THE FLOW CHART OF FIG. 19.
*4 REFER TO THE FLOW CHART OF FIG. 20.
RUNNING ON RUMBLE STRIPS NO DRIVER CORRECTIVE ACTN?
*1
NO
RETURN
YES
WHICH WHEEL ON RUMBLE STRIPS F/RH OR F/LH
F/LH
THE SAME FLOW OF RH-SIDE EXCEPT REPLACING RH BY LH
F/RH
DEVIATING TO RIGHT DIRECTION
ALERT DRIVER BY AUDITORY AND TACTILE WARNING
DRIVER'S CORRECTIVE ACTN?
*1
YES
RETURN
NO
R/RH ON RUMBLE STRIPS?
NO
RETURN
YES
CONTROL THE VEHICLE YAW ANGLE TO REDUCE HEADING ANGLE BY STEERING CONTROL OR BRAKE CONTROL
*3
*4
DRIVER'S CORRECTIVE ACTN?
*1
YES
RETURN
NO
F/LH ON RUMBLE STRIPS?
NO
RETURN
YES
CONTROL THE VEHICLE YAW ANGLE TO RETURN TO THE ROAD BY STEERING CONTROL OR BRAKE CONTROL
*3
*4
DRIVER'S CORRECTIVE ACTN?
*1
YES
RETURN
NO
R/LH ON RUMBLE STRIPS?
NO
YES
REDUCE THE VEHICLE SPEED TO STOP
*3
RETURN

FIG.22

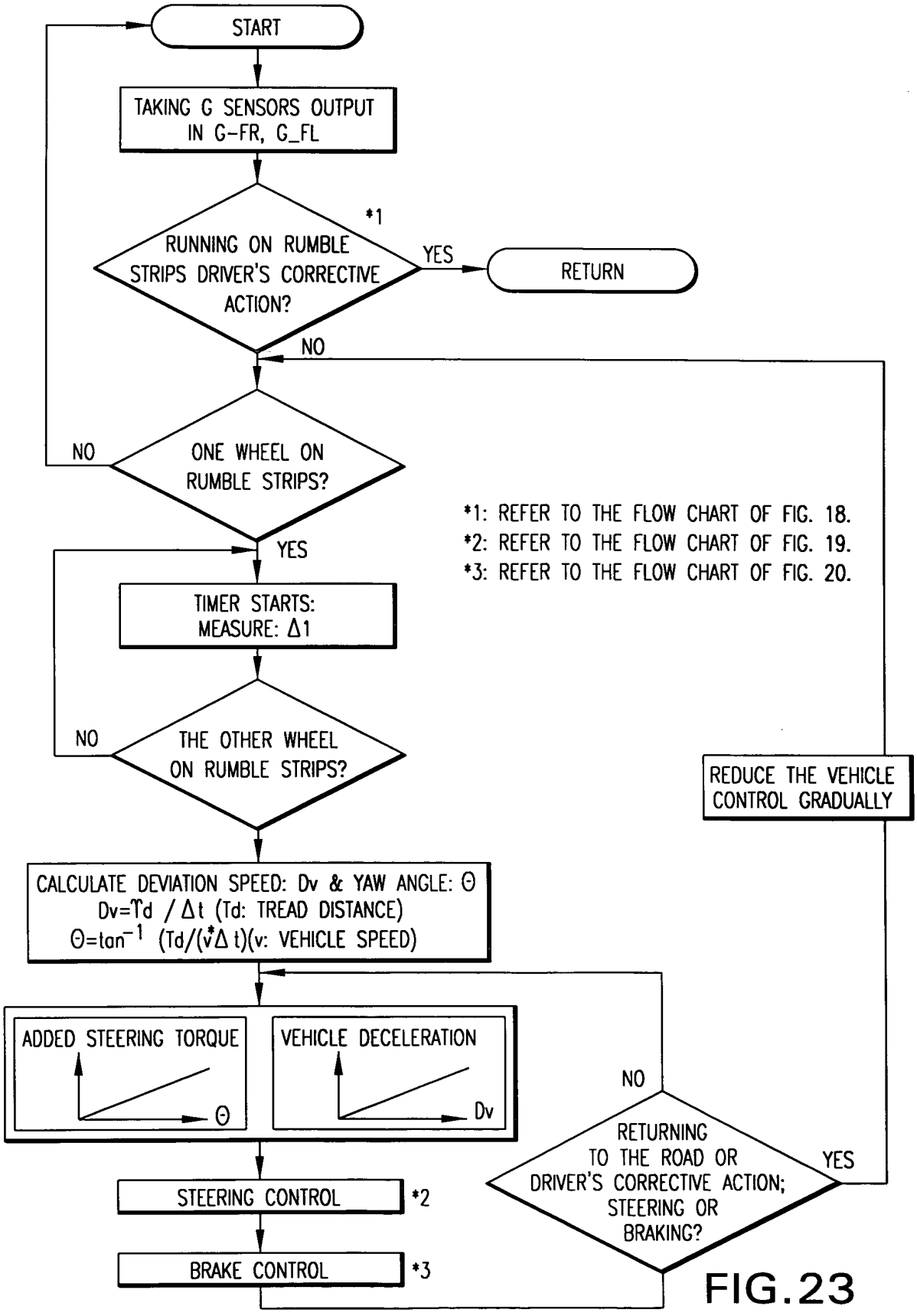
START
TAKING G SENSORS OUTPUT IN G-FR, G_FL
*1
RUNNING ON RUMBLE STRIPS DRIVER'S CORRECTIVE ACTION?
YES
RETURN
NO
NO
ONE WHEEL ON RUMBLE STRIPS?
YES
TIMER STARTS: MEASURE: Δ1
NO
THE OTHER WHEEL ON RUMBLE STRIPS?
CALCULATE DEVIATION SPEED: Dv & YAW ANGLE: Θ
Dv=Td / Δt (Td: TREAD DISTANCE)
Θ=tan⁻¹ (Td/(v*Δ t)(v: VEHICLE SPEED)
ADDED STEERING TORQUE
Θ
VEHICLE DECELERATION
Dv
STEERING CONTROL
*2
BRAKE CONTROL
*3
NO
RETURNING TO THE ROAD OR DRIVER'S CORRECTIVE ACTION; STEERING OR BRAKING?
YES
REDUCE THE VEHICLE CONTROL GRADUALLY
*1: REFER TO THE FLOW CHART OF FIG. 18.
*2: REFER TO THE FLOW CHART OF FIG. 19.
*3: REFER TO THE FLOW CHART OF FIG. 20.

FIG.23

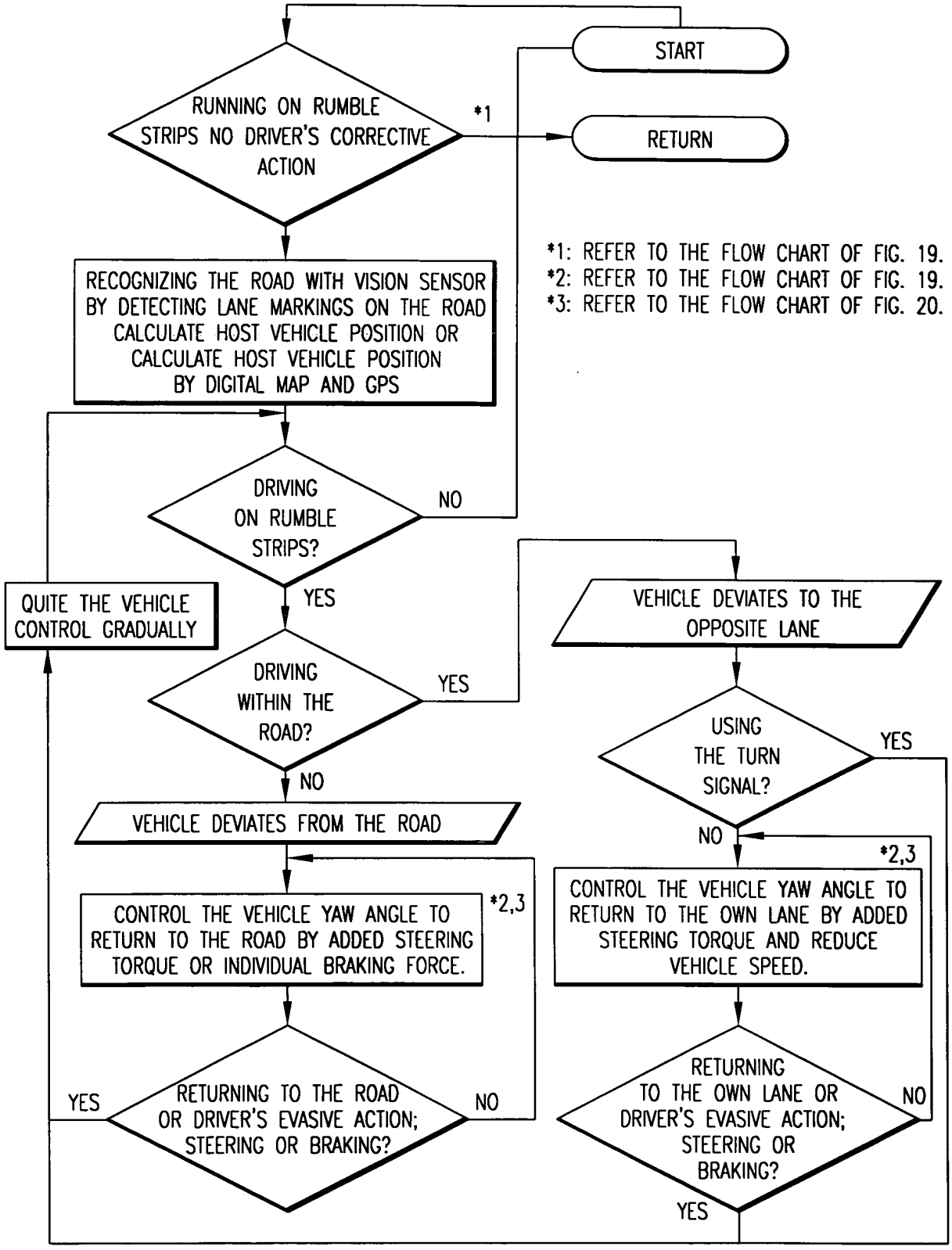
START
RUNNING ON RUMBLE STRIPS NO DRIVER'S CORRECTIVE ACTION
*1
RETURN
*1: REFER TO THE FLOW CHART OF FIG. 19.
*2: REFER TO THE FLOW CHART OF FIG. 19.
*3: REFER TO THE FLOW CHART OF FIG. 20.
RECOGNIZING THE ROAD WITH VISION SENSOR BY DETECTING LANE MARKINGS ON THE ROAD CALCULATE HOST VEHICLE POSITION OR CALCULATE HOST VEHICLE POSITION BY DIGITAL MAP AND GPS
DRIVING ON RUMBLE STRIPS?
NO
YES
QUITE THE VEHICLE CONTROL GRADUALLY
DRIVING WITHIN THE ROAD?
YES
NO
VEHICLE DEVIATES FROM THE ROAD
CONTROL THE VEHICLE YAW ANGLE TO RETURN TO THE ROAD BY ADDED STEERING TORQUE OR INDIVIDUAL BRAKING FORCE.
*2,3
RETURNING TO THE ROAD OR DRIVER'S EVASIVE ACTION; STEERING OR BRAKING?
YES
NO
VEHICLE DEVIATES TO THE OPPOSITE LANE
USING THE TURN SIGNAL?
YES
NO
*2,3
CONTROL THE VEHICLE YAW ANGLE TO RETURN TO THE OWN LANE BY ADDED STEERING TORQUE AND REDUCE VEHICLE SPEED.
RETURNING TO THE OWN LANE OR DRIVER'S EVASIVE ACTION; STEERING OR BRAKING?
NO
YES

FIG.24

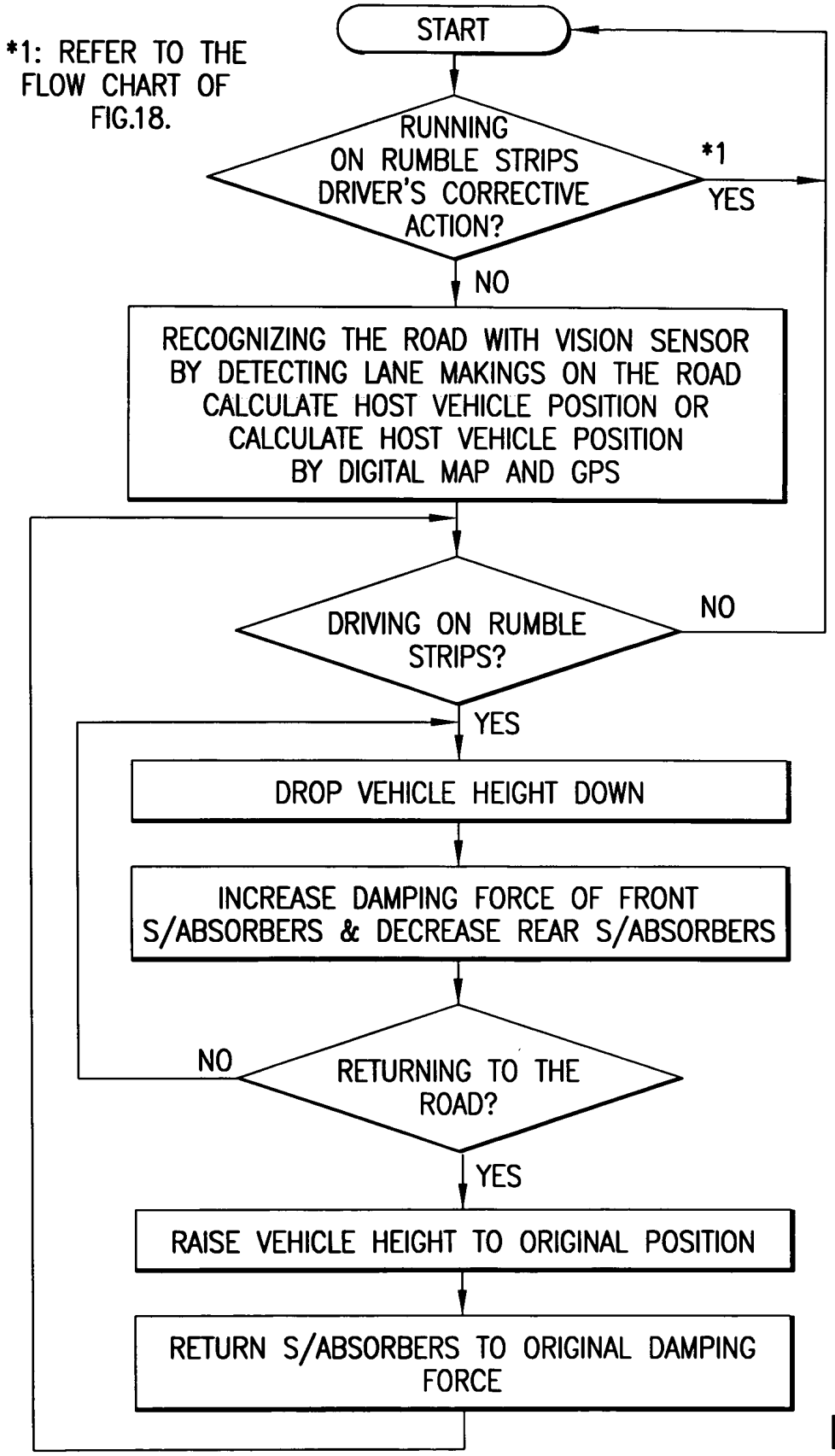
*1: REFER TO THE FLOW CHART OF FIG.18.
START
RUNNING ON RUMBLE STRIPS DRIVER'S CORRECTIVE ACTION?
*1
YES
NO
RECOGNIZING THE ROAD WITH VISION SENSOR BY DETECTING LANE MAKINGS ON THE ROAD CALCULATE HOST VEHICLE POSITION OR CALCULATE HOST VEHICLE POSITION BY DIGITAL MAP AND GPS
DRIVING ON RUMBLE STRIPS?
NO
YES
DROP VEHICLE HEIGHT DOWN
INCREASE DAMPING FORCE OF FRONT S/ABSORBERS & DECREASE REAR S/ABSORBERS
NO
RETURNING TO THE ROAD?
YES
RAISE VEHICLE HEIGHT TO ORIGINAL POSITION
RETURN S/ABSORBERS TO ORIGINAL DAMPING FORCE

FIG.25